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INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 6 : C02F 3/12, 3/30, 3/02, 3/22	A1	(11) International Publication Number: WO 95/24361 (43) International Publication Date: 14 September 1995 (14.09.95)

(21) International Application Number: PCT/AU95/00118

(22) International Filing Date: 10 March 1995 (10.03.95)

(30) Priority Data:
PM 4355 11 March 1994 (11.03.94) AU

(71) Applicant (*for all designated States except US*): CRC FOR WASTE MANAGEMENT AND POLLUTION CONTROL LIMITED [AU/AU]; High Street, Kensington, NSW 2033 (AU).

(72) Inventors; and
(75) Inventors/Applicants (*for US only*): HO, Kin, Man [GB/GB]; G/F, 72, Fuk Wah Street, Sham Shui Po, Kowloon, Hong-Kong (HK). GREENFIELD, Paul, F. [AU/AU]; 9 Rutlege Street, Indooroopilly, QLD 4068 (AU). SUBRAMANIAM, Kanthav, Anam [LK/AU]; 2/355 Moggill Road, Indooroopilly, QLD 4068 (AU). KELLER, Jurg [CH/AU]; 5/28 Sundridge Street, Taringa, QLD 4068 (AU).

(74) Agent: CULLEN & CO.; Level 12, 240 Queen Street, Brisbane, QLD 4000 (AU).

(81) Designated States: AM, AT, AU, BB, BG, BR, BY, CA, CH, CN, CZ, DE, DK, EE, ES, FI, GB, GE, HU, JP, KE, KG, KP, KR, KZ, LK, LR, LT, LU, LV, MD, MG, MN, MW, MX, NL, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, TJ, TM, TT, UA, UG, US, UZ, VN, European patent (AT, BE, CH, DE, DK, ES, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG), ARIPO patent (KE, MW, SD, SZ, UG).

Published
With international search report.

(54) Title: METHOD OF OPERATING A SEQUENCING BATCH REACTOR

(57) Abstract

A method of operating a sequencing batch reactor is described in which feed is supplied thereto by distributing feed into settled sludge in the bottom part of the reactor. A sequencing batch reactor having means for supplying feed to the bottom of the reactor is also described.

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METHOD OF OPERATING A SEQUENCING BATCH REACTOR

TECHNICAL FIELD

This invention relates to wastewater treatment and in particular to treatment of wastewater using sequencing batch reactors.

BACKGROUND ART

Meeting the increasingly stringent nitrogen (N) and phosphorous (P) effluent standards has had a major impact on the design and operation of wastewater treatment facilities dealing with domestic sewage with their typical unfavourable characteristics. Since the first success in achieving biological P removal in a continuous full-scale biological N removal plant in the 1970's, incorporation of biological P removal in a biological N removal plant is considered to be a generally achievable objective. Design and operation of biological nutrient removal (BNR) plants are now required to optimise these two parallel but interactive processes to maximise both nitrogen and phosphorus removal. Design and operation also requires simultaneous control of the associated sludge bulking problems resulting from the proliferation of filamentous bacteria.

The available BNR processes can be divided into continuously and intermittently operated systems. Continuously operated systems comprise a number of separate tanks or ponds through which wastewater and sludge is passed in various ways. Intermittently operated systems use a single reactor or pond, sometimes separated into zones by baffling, with only one pass of the wastewater through the reactor pond. Intermittent processes can therefore be characterised by their unique repeated sequencing time-oriented operation as compared to the space oriented operation of the continuous processes.

Intermittently operated systems can be either fed continuously or intermittently. They can be also subdivided into variable and constant volume systems. The variable volume systems accomplish solid-liquid separation in the same tank with subsequent withdrawal of the treated effluent (intermittent decant) while the constant volume intermittently operated facilities carry that out by a separate in-series secondary clarifier or basin with or without an underflow recycle returning the activated sludge back to the process.

In the operation of intermittently fed sequencing batch reactors (SBR) or sequencing batch ponds (subsequently called reactors) a substantial proportion of

the cycle time is used for the fill period. During this time, the part of the reactor volume that was discharged at the end of the previous cycle, is replaced by fresh sewage before aeration commences. In BNR operation of these reactors, the fill period is of major importance for the removal of both nitrogen and phosphorus based nutrients. There are strong indications that good nutrient removal performance is dependant on the structure and composition of the biomass flocs in the reactors. Flocs should ideally be of similar size, compact, spherical and without filamentous growth. This encourages simultaneous nitrification–denitrification during aeration periods and ensures good sludge settling properties. Several advantages of simultaneous nitrification–denitrification have been reported in the past including reduced requirements for biodegradable carbon (or COD) in the raw wastewater, reduced aeration requirements and part or complete elimination of anoxic reactors or sequences if net nitrate production can be kept at low levels. Achieving simultaneous nitrification–denitrification is therefore regarded as beneficial both in continuous and intermittent systems.

Existing technology such as the cyclic activated sludge system (CASS) uses so called selectors or contactors which are small volumes in the inflow part of the reactor. In these zones the inflowing feed is mixed with the return activated sludge which is pumped from the reactor bottom or from specific clarifiers. This has two major drawbacks. Firstly, only part of the sludge mass is contacted with the inflowing feed and secondly, it requires mechanical pumping of the sludge. This second requirement is not only operationally difficult but is likely to have a negative effect on the structure of the sludge flocs due to the mechanical stress exerted during the pumping action.

SUMMARY OF THE INVENTION

It is an object of this invention to provide a method of supplying feed to a sequencing batch reactor which allows maintenance of favourable floc characteristics and contributes to improved performance of the reactor during periods following the fill period.

The present inventors have surprisingly found that the manner in which feed is supplied to a sequencing batch reactor can effect floc formation and hence reactor performance. In particular, the inventors have found that even distribution of feed into the settled sludge bed can improve reactor performance. This

improvement is enhanced by including a non-mixed period into the FILL period of the reactor cycle.

In one aspect, the invention provides a method of supplying feed to a sequencing batch reactor, said method comprising distributing feed into settled sludge in the lower part of the reactor.

Feed can be distributed via a static distributor or a mobile distributor and can be supplied without mixing of reactor contents during at least a portion of, or throughout, the reactor fill period.

In a second aspect, the invention provides a sequencing batch reactor comprising at least one reactor vessel having feed means, aeration means, decant means and, optionally, mixing means; wherein said feed means comprises at least one distributor located at the bottom of said reactor vessel.

As in the method according to the first aspect, the reactor distributor can be a static or mobile distributor. Static distributors typically comprise a manifold suppling a plurality of distributor outlet lines. Alternatively, a static distributor can be a manifold with an extended upper surface having a plurality of outlets therein.

Mobile distributors typically comprise a member having a plurality of outlets therein which moves either linearly along the bottom of the reactor vessel or rotates about an axis vertically disposed with respect to the bottom of the reactor.

Other aspects of the invention will become apparent from the following detailed description.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a representation of the system used for laboratory scale evaluation of the method according to the invention.

Figure 2 presents influent and effluent concentrations in a laboratory scale SBR operating over a 5 month period.

Figure 3 depicts the cyclic performance of the laboratory scale SBR.

Figure 4 depicts concentration profiles of nitrogen compounds during the non-mixed FILL period of a laboratory scale SBR with respect to reactor height.

Figure 5 depicts phosphorous concentration profiles during the non-mixed FILL period with respect to reactor height of the same SBR the subject of Figure 4.

Figure 6 is a diagrammatic representation of an SBR.

DETAILED DESCRIPTION OF THE INVENTION

The following abbreviations are used herein:–

BASS	batch activated sludge system;
BNR	biological nutrient removal;
BPR	biological phosphorous removal;
CASS™	cyclic activated sludge system;
COD	chemical oxygen demand;
DO	dissolved oxygen;
F/M	food/microorganism ratio;
N	nitrogen;
NAS	non–agitated sequence;
NH_4–N	ammonium nitrogen;
NO_2–N	nitrite nitrogen;
NO_3–N	nitrate nitrogen;
NO_X–N	the sum of nitrite nitrogen and nitrate nitrogen;
OUR	oxygen uptake rate;
PO_4–P	phosphate phosphorous;
P	phosphorous;
RBCOD	readily biodegradable chemical oxygen demand;
SBR	sequencing batch reactor;
So/Xo	ratio of the initial substrate concentration to the initial biomass concentration;
TCOD	total chemical oxygen demand;
TKN	total Kjeldahl nitrogen;
TP	total phosphorous.

The term "sequencing batch reactor", abbreviated "SBR", as used in the following description and claims is not necessarily restricted to systems which are commonly called SBRs and includes any intermittently operated aerobic wastewater treatment system comprising as a process step settling of sludge within the reactor vessel. The scope of the appended claims is not therefore restricted to SBRs *per se* and the method of the invention is applicable to any intermittently operated aerobic wastewater treatment system comprising as a process step settling of sludge within

the reactor vessel.

Sequencing batch reactors (SBRs) require a non-agitated (non-mixed and non-aerated) SETTLE period to accomplish solid-liquid separation in the same tank with subsequent withdrawal of the treated effluent (intermittent decant), i.e. variable volume operation. During this non-agitated sequence (NAS), the biomass is allowed to concentrate at the bottom of the reactor and form a clear supernatant.

It is the extension of this special feature, which can be incorporated in an operating strategy not only for solid-liquid separation but more importantly for biosorption of the biodegradable organics and rapid environmental changes, which makes performance of the present reactor system superior to all conventional SBRs and continuous systems in terms of carbon, carbon and nitrogen, and carbon, nitrogen and phosphorus removal with positive sludge bulking control. This forms the basis of the present invention.

A typical SBR cycle is divided into five discrete time periods: FILL, REACT, SETTLE, DRAW and IDLE. With further combination of mixed or non-mixed and aerated or non-aerated operation, a total of 12 different reactions are possible.

The FILL period is the period of feed input into the reactor whereas the REACT period is a period of reaction without addition of fresh wastewater. In accordance with the invention, feed to the reactor during the FILL period is evenly distributed through the settled sludge blanket.

An SBR cycle is typically within the range of 2 to 24 hours. Ideally, a cycle is less than 8 hours provided that reactor throughput is not compromised by the shorter cycle time. The following table sets out a typically operating strategy and is based on a 6 hour cycle time.

TABLE I

Typical Operating Strategy

Reaction Sequence	Time (h)
1. Non-mixed FILL	1.25
2. Mixed FILL	1.25
3. Aerated mixed REACT 1	1.00

4. Non-mixed REACT	0.50
5. Aerated mixed REACT 2	1.50
6. SETTLE	0.33
7. DRAW	0.17
8. IDLE	0.00
TOTAL	6.00

The most important non-mixing sequence in determining good process performance and sludge characteristics is the non-mixed FILL sequence. With an appropriate feeding pattern, interrelated chain reactions leading to excellent process performance with good sludge settling characteristics can be initiated. The subsequent non-mixed non-aerated REACT sequences further ensure that these chain reactions proceed in the required direction, especially for handling carbon-deficient/nutrient-rich wastewaters. In both cases, the concentrated biomass at the bottom of the reactor allows more rapid development of any required environmental conditions either from anoxic to anaerobic or from aerobic to anoxic.

In the non-mixed FILL sequence, the method according to an embodiment of the invention is to introduce and distribute the incoming wastewater through the settled sludge blanket allowing intimate contact between the concentrated biomass and the undiluted incoming wastewater. Generation of localised high So/Xo ratios and self-adjusting floc loading allows rapid biosorption by the floc-forming bacteria. The enmeshment of the slowly biodegradable particulate COD under anaerobic conditions further allows more RBCOD to be generated by fermentation and enhances biological phosphorus removal without incorporating any primary sludge prefermentor. This is particularly desirable as the RBCOD concentration of some domestic wastewaters is around 25 to 50 mg L^{-1}.

A second important environmental condition created by such a feeding pattern is the development of a high NH_4–N concentration. As the influent wastewater in the method of the invention is slowly fed to the reactor floor without generating any significant mechanical mixing, the treated effluent in the sludge blanket from the previous cycle is gradually replaced by the influent wastewater. Furthermore, it was found that the level of biodegradable carbon required for the

denitrification process can be substantially reduced by use of the innovative feeding and operational strategy presented in this invention. A ratio of TCOD:TKN below the commonly reported minimal value of 7 for the influent wastewater was found to be suitable in this situation to achieve a high degree of nitrogen removal. As the TCOD:TKN ratio of domestic wastewater is very often <10 and frequently <7, this substantial saving in carbon source provides high potential in achieving future increasingly stringent effluent standards without any external addition of carbon.

Furthermore, in a single-tank system, i.e. without recycle, maintaining low effluent NO_3–N concentration in BASS relies on simultaneous nitrification-denitrification during the aerated sequence. This process is believed to depend on the formation of an anoxic fraction within the flocs which relies not only on the bulk DO concentration (0.5 to 3 mg L^{-1}), but more importantly on the floc characteristics.

The activity of the biomass in terms of the OUR or maximum specific growth rate and the floc diameter can be controlled by introducing the above-mentioned innovative feeding pattern during the non-mixed FILL with subsequent endogenous anaerobic sludge stabilisation resulting from achieving good simultaneous nitrification-denitrification. By imposing such alternating feast and famine environments, bacteria in the activated sludge culture capable of rapid enzymatic transport of soluble organic substrates under exogenous anaerobic conditions, and synchronous multiplication in the presence of molecular oxygen, will be selected. This leads to a high OUR and full restoration of the biosorptive capacity in the endogenous aerobic and anaerobic periods. Filaments which are slower substrate accumulating and incapable of denitrifying and polyP accumulating will be eliminated. Fast growing, starvation-susceptible filamentous organisms will also be removed during the extended period of endogenous metabolism. This mode of operation ensures a high OUR especially at the beginning of the aerobic period and good settling biological flocs of optimal size to facilitate simultaneous nitrification-denitrification of the wastewater. Consequently, simultaneous nitrification-denitrification is enhanced. The resulting pH gradient due to nitrification and rapid uptake of phosphate further enhance simultaneous nitrification-denitrification even at higher DO concentration.

With successful simultaneous nitrification-denitrification, the reaction

conditions required to achieve biological nitrogen and phosphorus removal change from anaerobic/anoxic/aerobic as in continuous BNR systems to anaerobic/aerobic only. This eliminates the presently unavoidable and uncontrollable sludge bulking problems due to alternating anoxic–aerobic conditions and the adverse effects on biological phosphorus removal caused by the carbon deficiency associated with incomplete denitrification.

It is believed that one of the major advantages the filamentous bacteria can have over the floc–forming bacteria is the way of growth of the former in the mixed liquor. The filamentous bacteria grow in profusion beyond the confines of the floc into the bulk medium bridging between flocs or completely in high abundance in the bulk solution. Consequently, they compete well with the floc–forming bacteria in completely mixed systems by having a larger surface area and lower substrate affinity. However, this privilege is no longer available if the feed is directed to the well thickened sludge after a prolonged SETTLE period which is normally not available in continuous clarifier systems. Another possible explanation of their way of growth is that the environmental conditions inside the floc are unfavourable. Consequently, they tend to extend their structure from the floc particularly to interfere with compaction during settling. Forcing them back to the floc during the SETTLE and non–mixed FILL period substantially reduces their chance of competing with the floc–formers.

The major benefit of this feed system into the reactors, is the intensive contacting of all biomass with the fresh feed stream entering the reactor. A large part of the water in the reactor from the previous cycle is in the supernatant and therefore not in contact with the sludge. This is advantageous since the supernatant water often contains nitrates which can be detrimental to the performance of the phosphorous removal processes.

This contacting period also provides a high food/microorganism ratio (F/M) which is beneficial for the growth of desirable floc–forming bacteria. Moreover, the presence of readily biodegradable chemical oxygen demand (RBCOD) favours the accumulation of internal carbon sources in the phosphorous removing bacteria. This stored carbon is then used in the phosphate uptake process during the aeration period and therefore facilitates the phosphorous removal process.

A major advantage of the present system is that the whole treatment process

can be done in one single vessel. The auxiliary equipment needed is also minimal since only feed and possibly a draw pump (and decanting weir), air blower and a mechanical mixer are needed to operate the reactors. In a minimal configuration, outflow (draw) can be achieved by a simple overflow mechanism and mechanical mixing might not be necessary in all cases.

Compared to existing continuous and intermittent BNR plants this design offers substantially reduced capital costs, simple operation and, based on the results obtained to date, excellent treatment performance in regards to COD, total N and total P. Experiments also show that it can handle very high strength wastewater (N and P) which is common in industrial treatment systems.

Although similar non-mixed fill sequences have been used in sequencing batch reactor cycles prior to this invention, the objectives of the use were different and the substantial benefits offered by such a simple modification were ignored. Chiesa *et al* (*Biotechnology and Bioengineering 27*, 562–569, 1985) carried out bench-scale studies using the non-mixed FILL sequence to generate substrate gradient for their feast/famine population selection in sludge bulking control. In the experiments conducted by Manning and Irvine (*Journal of Water Pollution Control Federation*, 59(1), 13–18, 1985), the non-mixed FILL sequence was incorporated in the control system to minimise the contact between the biomass and the organic substrates while a mixed dump-FILL sequence was used to develop phosphorus removal sludge. The non-mixed FILL sequence was also trialled by Oomori *et al.* (*Proceedings of the Australian Water and Wastewater Association 13th Federal Convention*, pp. 359–363, 1989) as an operating strategy in their pilot studies. Full-scale operation using this reaction sequence included Irvine *et al.* (*Journal of Water Pollution Control Federation, 57*(8), 847–853, 1985); Ketchum *et al.* (*Journal of Water Pollution Control Federation*, 59(1), 13–18, 1987) and Nielson and Thompson (*Journal of Water Pollution Control Federation 60*(2), 199–205, 1988). However, none of the prior art describes or hints at supply of feed to the reactor by direct and even distribution to the settled sludge blanket during the non-mixed FILL sequence.

So that the invention may be better understood, non-limiting examples follow.

EXAMPLE 1

The method of the invention was applied to abattoir (slaughter house) wastewater high in both nutrients and carbon. The feed used in this laboratory-scale study was effluent from an anaerobic pond of an abattoir wastewater system.

The SBR was operated at room temperature (20 ± 2°C) with an hydraulic retention time and solids retention time of 1.5 days and 20 days respectively. The reactor had a volume of 4.5 L and feed was distributed beneath the sludge blanket via a tube terminating at the bottom of the reactor vessel near the centre thereof. The reactor was seeded with sludge from a nitrogen removing domestic sewage treatment plant. The reactor sequence periods are set out in Table II while the physical aspects of the process are shown in Figure 1.

TABLE II

Reactor Sequence Periods

	Time (h)	
Reaction Sequence	Experimental Phase 1	Experimental Phase 2
Non-mixed Fill	2.5	2.5
Aerated mixed React 1	3.0	1.0
Non-aerated mixed React	0	0.5
Aerated mixed React 2	0	1.5
Settle	0.33	0.33
Draw	0.17	0.17

Grab samples of wastewater were collected once every 5 to 7 days and were stored under anaerobic conditions at 4°C. Influent wastewater from a feed drum was intermittently fed to the system at a rate of 400 mL h^{-1}, by a variable-speed Masterflex pump. Effluent discharge was by gravity. Mixing was provided by a magnetic stirrer. Diffuser stones were used to distribute air to the reactor. Excess activated sludge wasting was performed in every cycle at the end of the aerated mixed REACT 2 period to maintain the sludge age. All operations (i.e. fill, aeration, mixing and effluent discharge) were controlled by an IBM compatible

computer.

The performance of the reactor, as determined from the daily influent TKN and PO_4–P, and effluent NO_x–N and PO_4–P, is presented in Figure 2. In Figure 2, the following symbols are used: influent PO_4–P, closed circle; influent TKN, closed triangle; effluent NO_x–N, open triangle; and, effluent PO_4–P, open circle.

After 105 days, the operating conditions were changed slightly, incorporating a 30 minutes non–aerated mixing sequence after one hour of aeration period (Phase 2 of Table II). This was based on an analysis of the cyclic behaviour of the reactor at day 95.

Figure 2 clearly shows that the reactor achieved a very high degree of nutrient removal, particular in respect of PO_4–P. Once the BNR system was established, consistently low levels of phosphate were recorded in the effluent. For a period of over two months, each daily phosphate measurement was below the detection limit of the analytical method used (ion chromatography) which is at least 0.5 mg/L PO_4–P. This result could be maintained even under large fluctuations in the influent P concentration reaching 60 mg/L PO_4–P in some samples. The effluent COD and TKN concentrations were between 100–200 mg/L and 5–14 mg/L respectively.

These results show the very high capacity of this system and the stability of the BNR processes once established. It is believed that this stability is based on the development of a particular biomass floc structure which could be essential to achieve simultaneous nitrification/denitrification (SND). This enables consistent NO_x–N effluent concentrations below 15 mg/L which in turn is necessary to achieve complete anaerobic conditions in the FILL period. Consequently, the P removing organisms are not competing with denitrifiers for the incoming RBCOD which results in high carbon accumulation and phosphate release by these micro–organisms. The measured SVI values in the reactor remained below 100 mL/g at all times, providing further evidence that the flocs in this system are of a compact, dense structure.

The cyclic performance of the reactor was assessed and the results of this experiment are presented in Figure 3. Operational conditions were the same as detailed above with the exception that the FILL period comprised a 2 hour non–mixed FILL followed by a 30 minute mixed FILL. In Figure 3, plots of NH_4–N,

NO_x–N and PO_4–P concentrations are indicated by diamonds, squares and triangles, respectively.

Figure 3 shows that the high S_0/X_0 ratio generated by incorporating a non-mixed FILL sequence at the beginning of a cycle allows simultaneous nitrification-denitrification with the in-reactor NO_x–N concentration being less than 5 mg/L during the entire air-on sequences. It can be seen the NO_x–N concentration at the end of the cycle was low which greatly enhanced anaerobic RBCOD uptake and P release. The highest PO_4–P in the sludge blanket recorded was 56 mg/L. However, PO_4–P uptake in the presence of DO was rapid and complete elimination of PO_4–P was achieved during the second aerated mixed REACT (Figure 3).

EXAMPLE 2

Experiments were conducted to assess concentration profiles over reactor height during the non-mixed FILL period of an SBR. A laboratory scale SBR of 12 L volume was used and the process run with a 18 hour hydraulic retention time and 20 day sludge age in a temperature controlled room (20 ± 2°C). The wastewater used in this experiment was raw sewage from a domestic sewage treatment plant. The FILL period was 2.5 hr without mixing. Feed was supplied via a tube terminating with a T-piece. The arms of which distributed feed evenly into the settled sludge at the bottom of the reactor. Other operational conditions were generally as described above in Example 1. Samples were taken at various times after feeding had been initiated and either at the reactor bottom or from various heights above the reactor bottom.

Results are presented in Figures 4 and 5. In Figure 4, NH_4–N (triangles), NO_3–N (squares) and NO_2–N (diamonds) concentrations are shown for samples taken 10 min (open symbols), 1 hr 15 min (stippled symbols) and 2 hr 25 min (filled symbols) after feeding. PO_4–P concentrations presented in Figure 5 are similarly of samples taken at 10 min (open symbols), 1 hr 15 min (stippled symbols) and 2 hr 25 min (filled symbols) after feeding.

The purpose of the non-mixed FILL sequence is to allow the biomass to thicken to a high concentration at the bottom of the reactor, with the liquid forming a clear supernatant. The NO_x–N remaining from the previous cycle is quickly removed in the sludge blanket due to the high biomass and substrate concentration in that part of the reactor (Figure 4). The latter condition results from distributing

the feed at the bottom of the reactor. After establishment of truly anaerobic conditions, instead of anoxic conditions, in the sludge blanket a high anaerobic P release by the BPR bacteria can be observed (Figure 5).

EXAMPLE 3

In this example, an SBR is described in which feed is distributed at the bottom of a reactor vessel. The SBR will be exemplified with reference to Figure 6 which diagrammatically depicts a pilot SBR plant comprising two 10,000 L reactor vessels. SBR's conveniently comprise two reactor vessels so that with staggered cycles of operation, supply of wastewater to the SBR is essentially continuous.

Referring to Figure 6, there is shown SBR 1 comprising reactor vessels 2 and 3. SBR 1 includes a feed distributor for each vessel. With reference to reactor vessel 2, components of distributor 4 are pump 5, which supplies feed to manifold 6 mounted above the vessel. Manifold 6 feeds a plurality of drop tubes, one of which is indicated at 7. The drop tubes each terminate in a distributor pipe, one of which is indicated at 8. Each distributor pipe includes a plurality of upwardly directed outlets.

It will be appreciated that distributor 9 of reactor vessel 3 comprises the same components as distributor 4.

During a FILL period, feed is delivered to the distributor via the pump. Feed exiting distributor pipe outlets allows even distribution of the feed through settled sludge in the bottom of a reactor vessel.

It should be appreciated that various other changes and modifications can be made to the embodiments exemplified without departing from the spirit of the invention which is limited only by the scope of the claims appended hereto.

CLAIMS

1. A method of supplying feed to a sequencing batch reactor, said method comprising distributing feed into settled sludge in the lower part of the reactor.

2. Method according to claim 1, wherein said feed is distributed via a static distributor.

3. Method according to claim 1, wherein said feed is distributed via a mobile distributor.

4. Method according to claim 1, wherein feed is supplied without mixing of reactor contents during at least a portion of the reactor fill period.

5. Method according to claim 1, wherein feed is supplied without mixing of reactor contents during all of the reactor fill period.

6. A sequencing batch reactor comprising at least one reactor vessel having feed means, aeration means, decant means and, optionally, mixing means; wherein said feed means comprises at least one distributor located at the bottom of said reactor vessel.

7. Reactor according to claim 6, wherein said distributor is a static distributor.

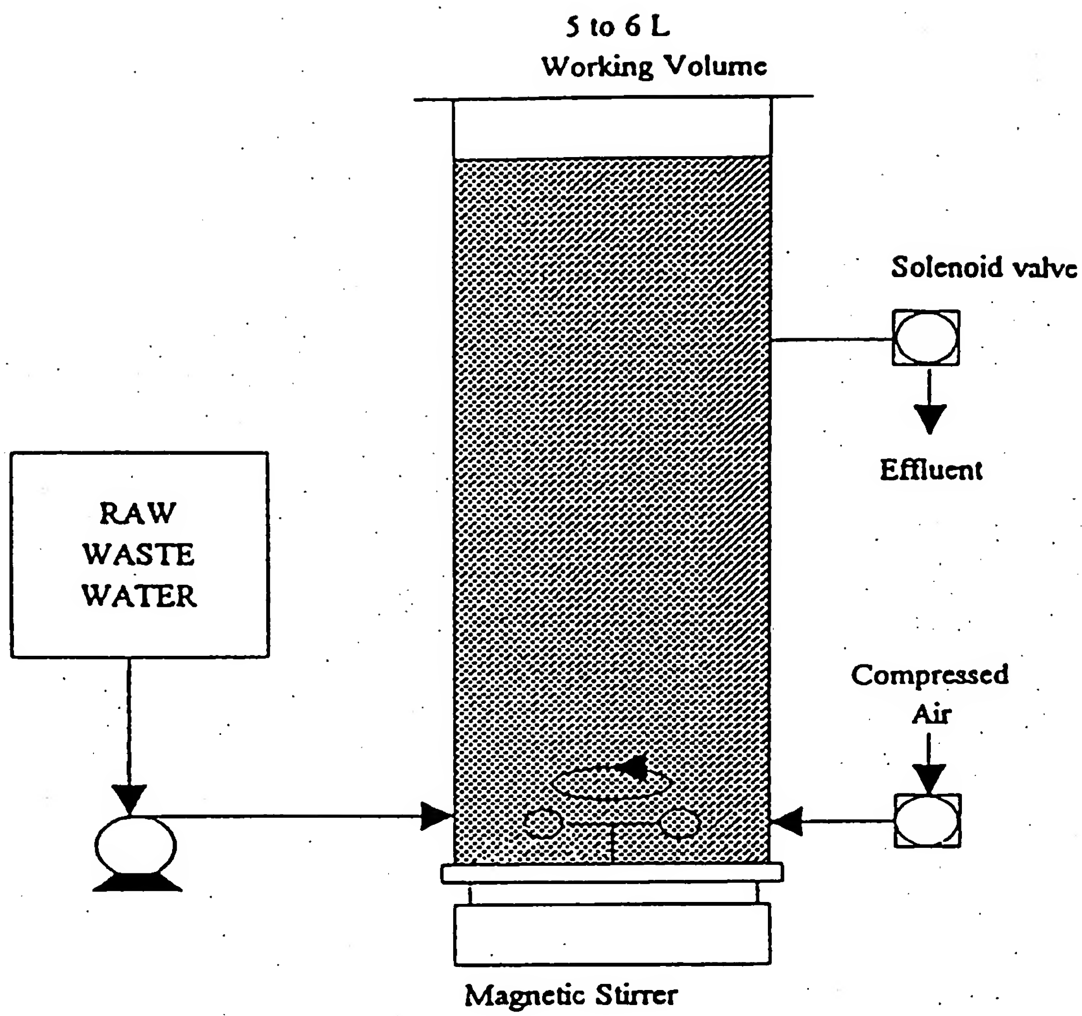
8. Reactor according to claim 7, wherein said static distributor comprises a manifold supplying a plurality of distributor outlet lines.

9. Reactor according to claim 7, wherein said distributor comprises a manifold with an extended upper surface having a plurality of outlets therein.

10. Reactor according to claim 6, wherein said distributor is a mobile distributor.

11. Reactor according to claim 10, wherein said distributor comprises a member having a plurality of outlets therein, which member moves linearly along the bottom of said reactor vessel.

12. Reactor according to claim 10, wherein said distributor comprises a member having a plurality of openings therein, which member rotates about an axis vertically disposed with respect to the reactor vessel bottom.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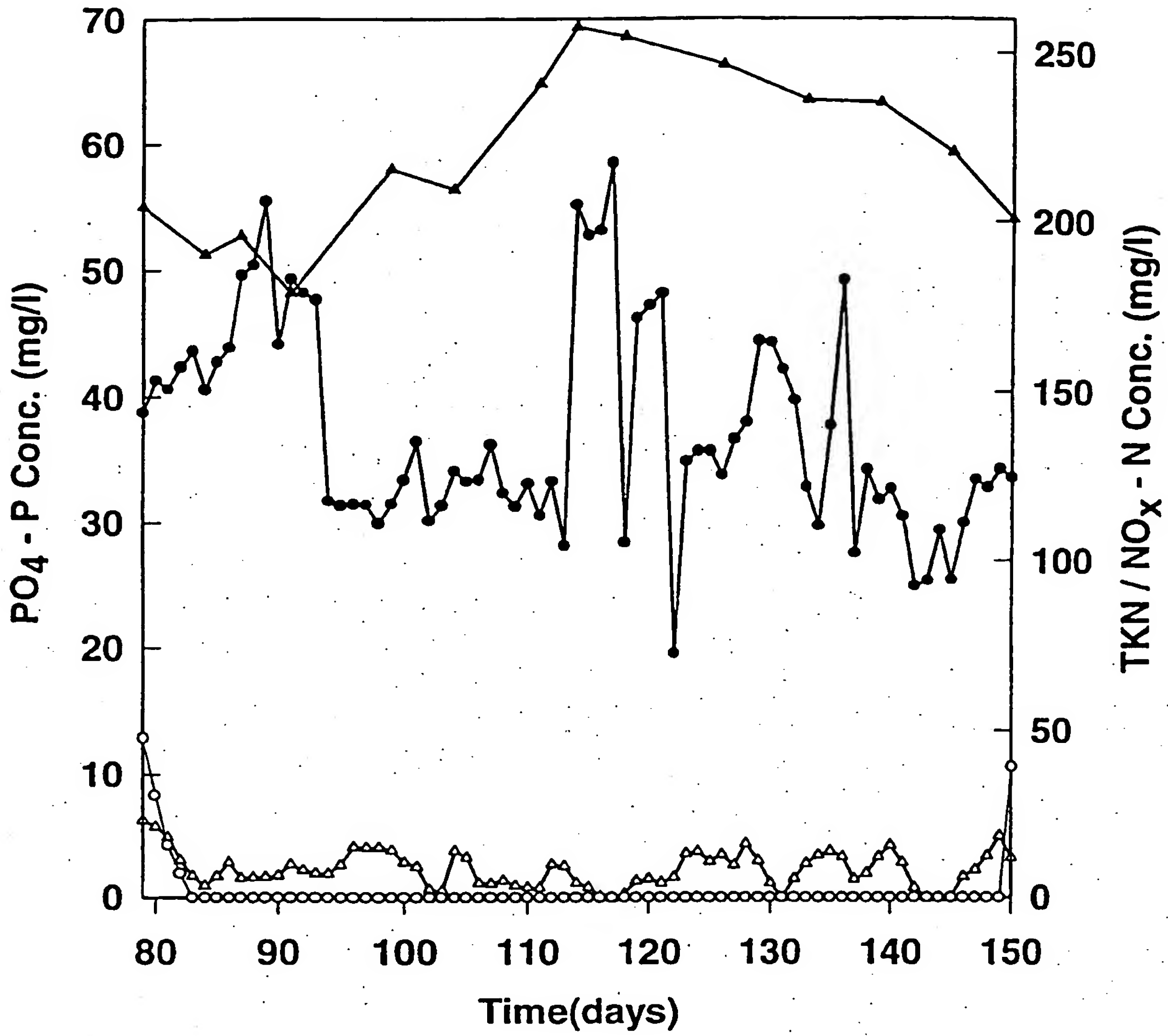
Working Volume
Solenoid valve
Effluent
RAW
WASTE
WATER
Compressed
Air
Magnetic Stirrer

Fig.1.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60
50
40
30
20
10
0
PO4 - P Conc. (mg/l)
250
200
150
100
50
0
TKN / NOx - N Conc. (mg/l)
80
90
100
110
120
130
140
150
Time(days)

Fig. 2.

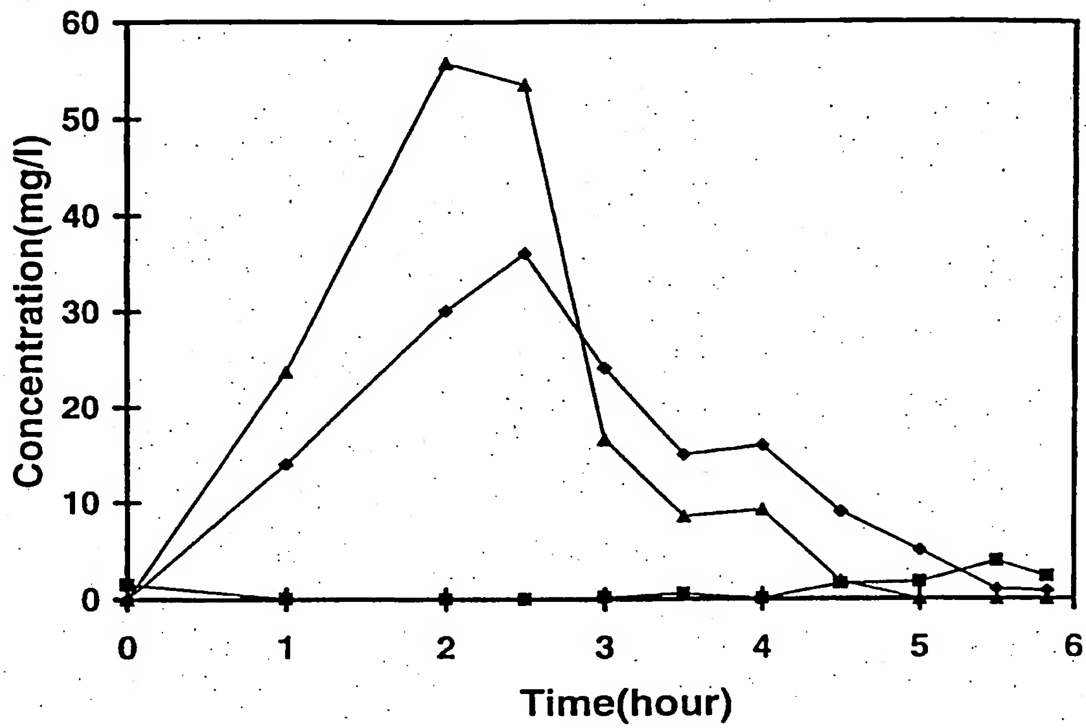

Fig. 3.

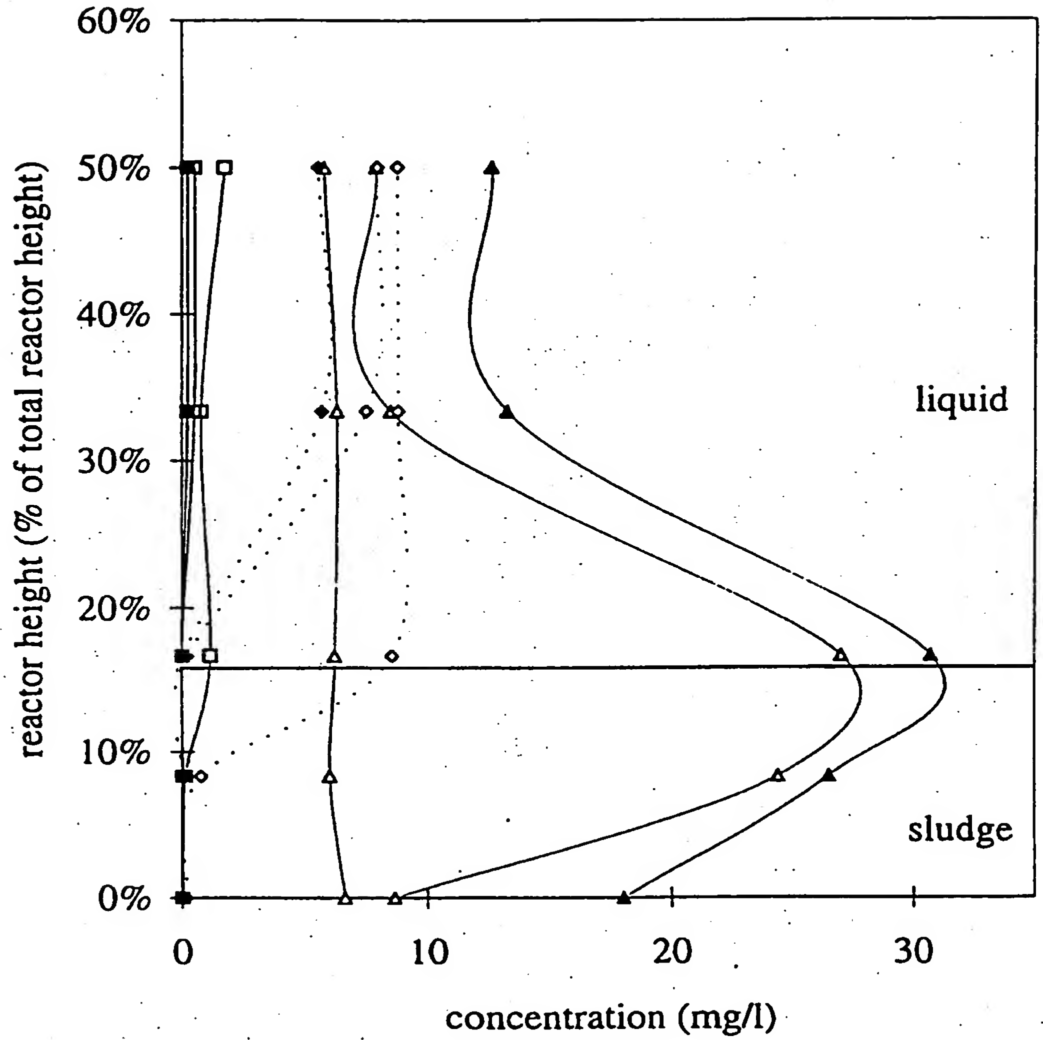
60%
50%
40%
30%
20%
10%
0%
reactor height (% of total reactor height)
liquid
sludge
0
10
20
30
concentration (mg/l)

Fig. 4.

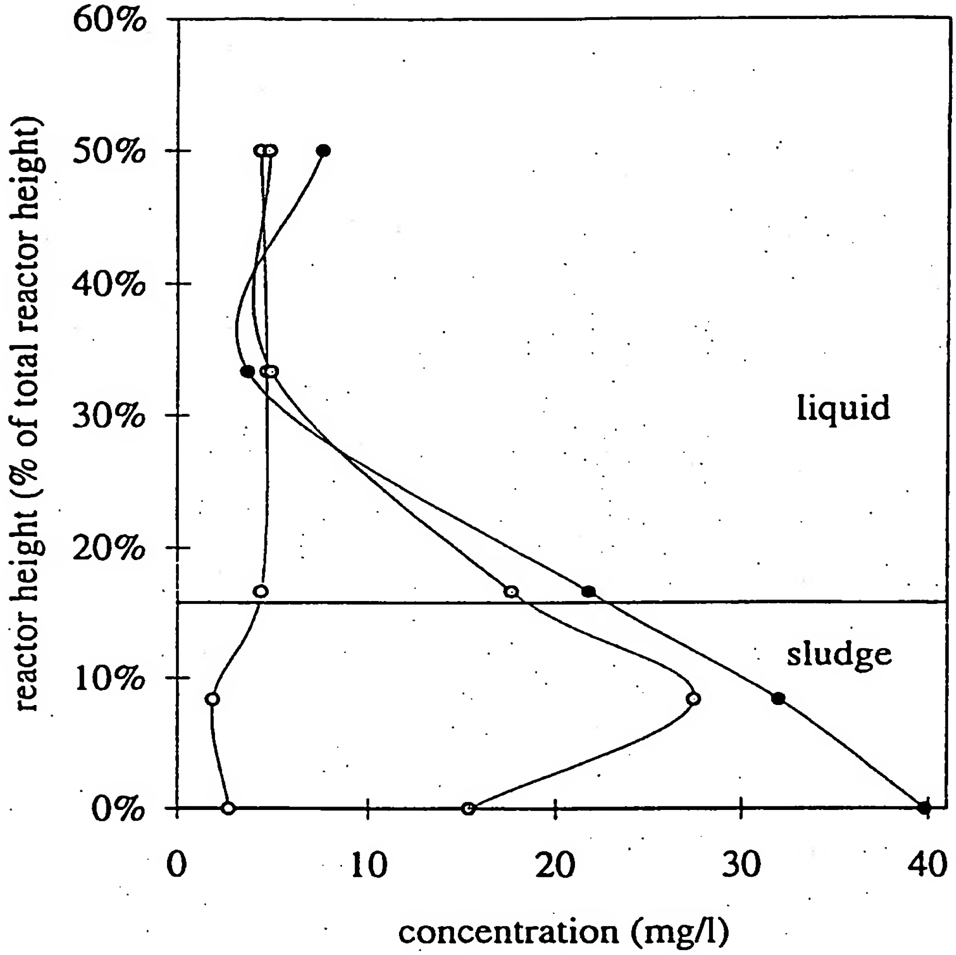
60%
50%
40%
30%
20%
10%
0%
reactor height (% of total reactor height)
liquid
sludge
0
10
20
30
40
concentration (mg/l)

Fig. 5.

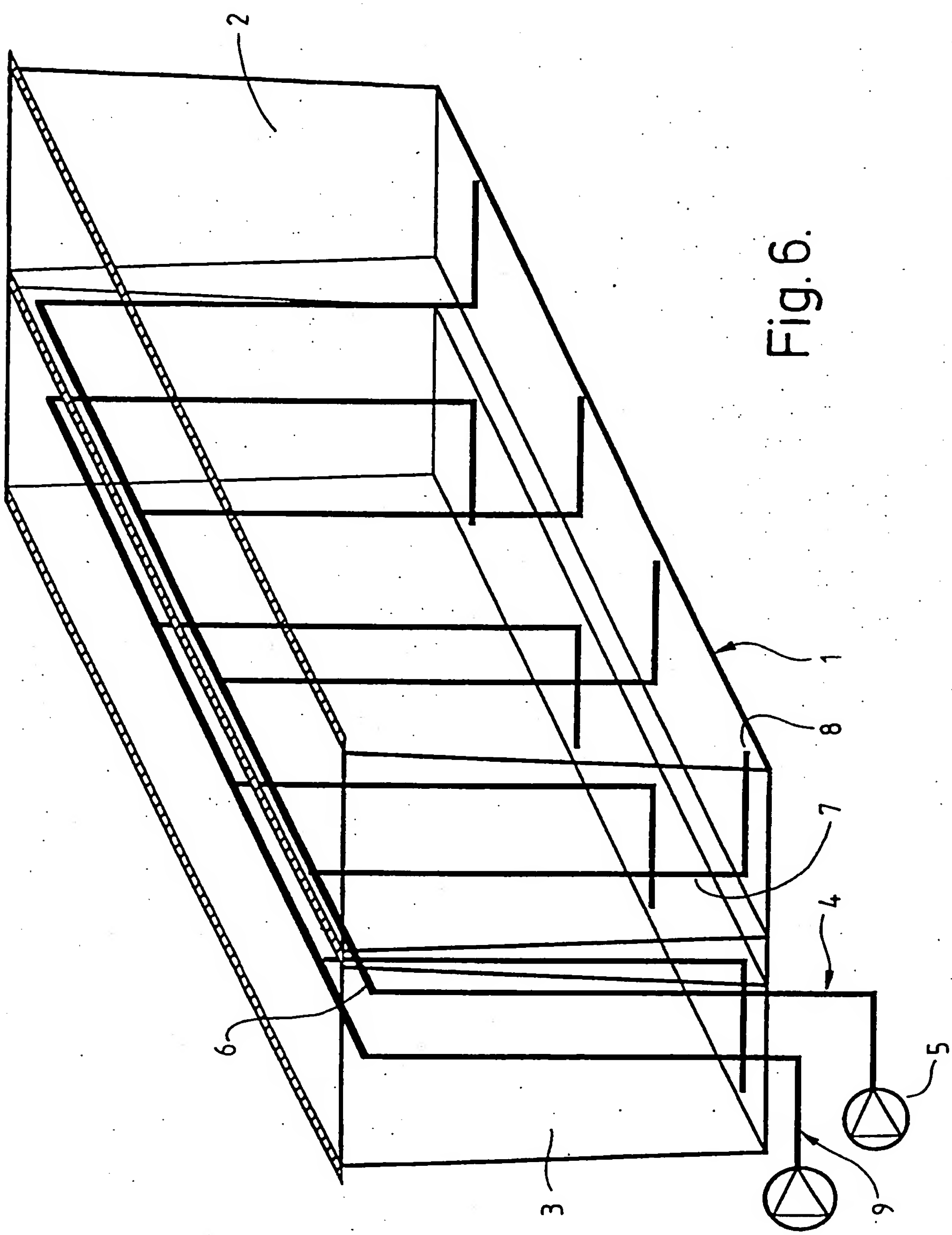

Fig. 6.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/AU 95/00118

A. CLASSIFICATION OF SUBJECT MATTER

Int. Cl.[6] C02F 3/12, C02F 3/30, C02F 3/02, C02F 3/22

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC: C02F 3/12, C02C 1/06 (FULL)
IPC: C02F 3/30, 3/02, 3/22, 3/20; B01F 3/08, 3/12, 7/- (KEYWORD)

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
AU: IPC as above

Electronic data base consulted during the international search (name of data base, and where practicable, search terms used)
(a) DERWENT: (BATCH OR REACTOR OR BIOREACTOR OR INTERMITTENT:) AND (IPC AS ABOVE) (C02F)
(b) DERWENT: (SEWAGE OR WASTE () WATER OR SLUDGE OR EFFLUENT) AND (IPC AS ABOVE) (B01F)
(c) JAPIO: AS FOR DERWENT: (IPC) AND (KEYWORDS)
(d) DERWENT: (SEQUENCING () BATCH () REACTOR)
(e) CHEM ABS: (BATCH OR REACTOR OR BIOREACTOR OR INTERMITTENT:) AND (SEWAGE OR WASTE () WATER OR SLUDGE OR EFFLUENT) AND (FEED OR FED OR INFLOW OR INLET OR INFLUENT) AND (BOTTOM OR BASE OR LOW OR FLOOR)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to Claim No.
X	US 5021161 A (CALLTHARP) 4 June 1991 column 1, lines 39-47, column 5, lines 3-8, column 6, lines 48-60, Figure 2	1, 2, 4, 5, 6-9
X	US 4775467 A (CALLTHARP et al.) 4 October 1988 column 4, line 60-column 5, line 14, Figure 2	1, 2, 6-9
Y	column 1, lines 31-46	4, 5

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier document but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search 26 June 1995	Date of mailing of the international search report 29 JUNE 1995 (29.06.95)
Name and mailing address of the ISA/AU AUSTRALIAN INDUSTRIAL PROPERTY ORGANISATION PO BOX 200 WODEN ACT 2606 AUSTRALIA Facsimile No. 06 2853929	Authorized officer D J L Lackie D J L LACKIE Telephone No. (06) 2832272

INTERNATIONAL SEARCH REPORT

International application No.
PCT/AU 95/00118

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate of the relevant passages	Relevant to Claim No.
Y	US 4997557 A (ANDERSEN) 5 March 1991 column 1, lines 12-14	4, 5
X	US 4596658 A (MANDT) 24 June 1986 column 4, lines 36-55, Figure 2	1, 2, 6-9
X	US 4883602 A (ANDERSON) 28 November 1989 column 9, line 61-column 10, line 15, Figure 6	1, 2, 6, 7
X	AU 26527/92 A (MURPHY) 18 March 1993 pages 8, 9, claim 1, Figure 2	1, 2, 6, 7
X	PATENT ABSTRACTS OF JAPAN, C-804, page 37, JP02-284696 A (HITACHI PLANT ENG & CONSTR CO LTD) 22 November 1990 abstract	1, 3, 6, 10-12
X Y	PATENT ABSTRACTS OF JAPAN, C-463, page 112, JP 62-149399 A (EBARA INFILCO CO LTD) 3 July 1987 abstract abstract	1, 2, 6-9 4, 5
Y	DERWENT ABSTRACT ACCESSION NO. 93-277659/35, Class D 15, JP 05-192687 A (INAX CORP) 3 August 1993 abstract	4, 5
X	CA 2041329 A (BIO CLEAR TECHNOLOGY INC) 27 October 1992 page 8, last paragraph, Figure 2	6
P,X	US 5395527 A (DESJARDINS) 7 March 1995 column 6, lines 34-46, columns 11-12, Figure 1	1, 2, 4, 5, 6-9
A	JOURNAL WATER POLLUTION CONTROL FEDERATION, volume 57, Number 12, issued December 1985, (Water Pollution Control Federation, Washington, DC), Herzbrun et al., "Biological Treatment of Hazardous Waste in Sequencing Batch Reactors", pages 1163-1167 whole document	1-12

INTERNATIONAL SEARCH REPORT
Information on patent family membe

International application No.
PCT/AU 95/00118

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document Cited in Search Report		Patent Family Member					
US	4775467	CA	1273718	US	4645592	US	4724073
US	4596658	CA	1249228				
AU	26527/92	AU	37780/93	EP	575567	EP	626877
		FI	933177	HU	9301908	NO	931999
		US	5186821	US	5234580	US	5352356
		US	5384049	WO	9304759	WO	9316781

END OF ANNEX